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EVALUATION OF THE EFFECTIVENESS OF CHLORINATION AT THE LITTLETON WASTEWATER TREATMENT PLANT, LITTLETON, COLORADO, MAY 15-23, 1972

Environmental Protection Agency
Denver, Colorado

August 1972

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EVALUATION OF THE EFFECTIVENESS OF CHLORINATION AT THE LITTLETON WASTEWATER TREATMENT PLANT LITTLETON, COLORADO

May 15-23, 1972

TECHNICAL SUPPORT BRANCH
SURVEILLANCE AND ANALYSIS DIVISION
U. S. ENVIRONMENTAL PROTECTION AGENCY
REGION VIII

August 1972

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I. Introduction

Region VIII of the United States Environmental Protection Agency developed an Accomplishment Plan for the Metropolitan Denver-South Platte River Basin areas. As a result of implentation of this plan a study was made at the Littleton, Colorado, Wastewater Treatment Plant. The purpose of this study is to evaluate the effectiveness of chlorination at the Littleton plant in providing satisfactory disinfection before discharge to the South Platte River. An evaluation was also made of chlorine residuals downstream from the Littleton outfall.

II. Description of Plant

A schematic diagram of Littleton's high rate trickling filter wastewater treatment plant is shown in Figure 1. The two 30 foot primary clarifiers and the No. 1 and No. 2 digesters are operational but are not in service. The average daily flow from January through May, 1972, was 4.25 MGD. During the survey the highest recorded flow (peak flow during any one day) was 6.19 MGD.

Disinfection with chlorine is used at the Littleton facility to meet the Colorado Water Quality Standards. The plant effluent passes through a Parshall flume and chlorine (the amount of chlorine varies with flow) is applied. The effluent enters the outfall line, passes through an inverted siphon, and flows to the river. The outfall is approximately 2,000 feet downstream from the treatment plant.

Presently the operational mode at Littleton, with respect to chlorination, is to adjust the chlorine dosage to obtain a chlorine residual at the outfall of 0.2 mg/l. In most cases a chlorine dosage of about 3.5 mg/l is needed to maintain the desired 0.2 mg/l chlorine residual at the outfall.

III. Applicable Water Quality Criteria

The bacteriological standard that applies to the South Platte River for the reach that receives wastewater effluent from the Littleton facility requires the log mean of fecal coliform organisms to be less than 1000 per 100 ml. and no more than 2000 per 100 ml. in greater than ten (10) percent of the samples collected in any thirty (30) day period. In addition, the effluent must be free from biocides, toxic, or other deleterious substances in levels, concentrations, or combinations sufficient to be harmful to aquatic life.

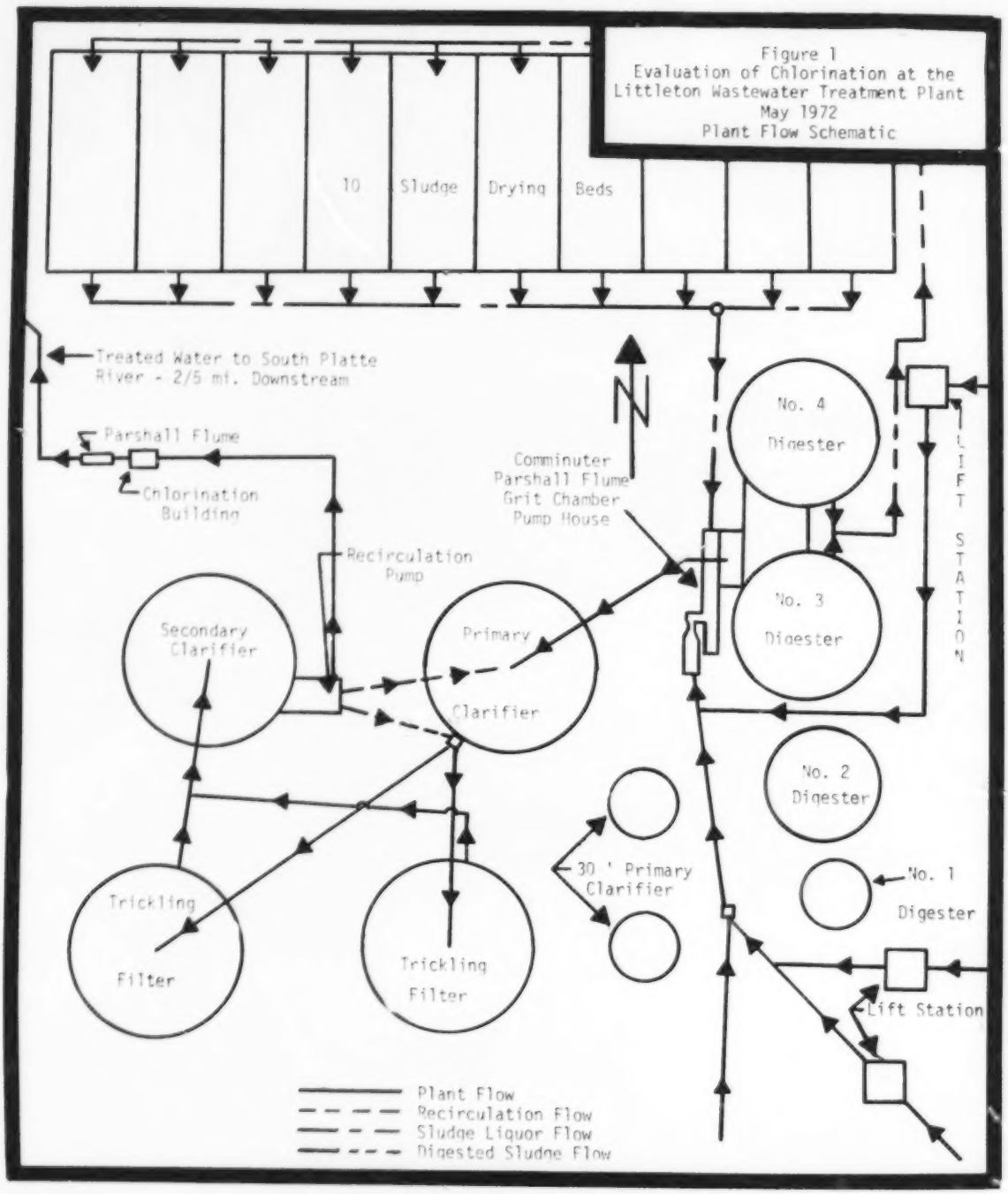
Figure 1
Evaluation of Chlorination at the
Littleton Wastewater Treatment Plant
May 1972
Plant Flow Schematic
10 Sludge Drying Beds
Treated Water to South Platte
River - 2/5 mi. Downstream
Parshall Flume
Chlorination
Building
Recirculation
Pump
Comminuter
Parshall Flume
Grit Chamber
Pump House
No. 4
Digester
No. 3
Digester
No. 2
Digester
No. 1
Digester
LIFT STATION
Secondary
Clarifier
Primary
Clarifier
30 ' Primary
Clarifier
Trickling
Filter
Trickling
Filter
Lift Station
Plant Flow
Recirculation Flow
Sludge Liquor Flow
Digested Sludge Flow

IV. Sampling Procedure

The primary purpose of disinfection is the destruction of all pathogenic organisms. Since pathogenic organisms are few in number and very difficult and time-consuming to isolate and identify the coliform group of organisms are used as indicators of contamination. Total coliform organisms include those found in the intestinal tract of human beings and other warmblooded animals, and in plants, soil, air, and the aquatic environment. Fecal coliforms include only those found in the intestinal tract of humans and warmblooded animals. Bacteriological samples were collected during this study and were analysed for both the total and fecal coliform group of microorganisms.

Two factors which are extremely important in disinfection are length of contact time and concentration of chlorine. At Littleton, the length of contact time is equal to the time after the chlorine is added until the flow is discharged from the outfall line. This contact time varies inversely with flow (i.e., a higher flow yields a shorter contact time).

Concentration of chlorine could be represented by either the amount of chlorine added to the plant effluent (chlorine dosage) or the amount of chlorine remaining at the end of the contact time (chlorine residual). Normally chlorine residual is used to represent concentration of chlorine. However, for this report chlorine dosage was chosen to represent concentration of chlorine since this discussion is directed to operation of the disinfection unit and chlorine dosage is the parameter most easily controlled by plant personnel.

A. Method for Determination of Length of Contact Time

The length of contact time in Littleton's outfall line was approximated by conducting several dye studies. Approximately two (2) milliliters of rhodamine-WT dye was added to the outfall line at the point of chlorine application to the effluent flow. Grab samples were taken at the outfall every fifteen (15) seconds. The fluorescence of each sample as measured by a fluorometer was attained. The contact time was assumed to be equal to that time from when the dye was added until the peak fluorescence was achieved. The exact peak fluorescence and thus contact time was calculated through interpolation.[1] (See Table A-1 in Appendix A for data.)

[1] It was assumed that the fluorescence, if it was continually monitored, would follow a normal distribution. Thus, standard interpolation methods were followed.

The relationship between length of contact time and flow is shown in Figure 2. A line of best fit was drawn through the data and shows that for an average daily flow of 4.25 MGD, the corresponding contact time would be about 18 minutes. When discussing disinfection, high flows are most critical because contact time is shortest (as shown in Figure 2), hence emphasis will be on the higher flows in this discussion.

B. Methods for Evaluation of Effectiveness of Chlorination

To determine the effectiveness of chlorination, the following factors were evaluated: flow, chlorine dosage, chlorine residual, and total and fecal coliform concentration. Two (2) sampling locations were chosen, one at a point just prior to where the chlorine was applied and one at the outfall. Sampling locations upstream and downstream from the outfall were also monitored.

Bacteriological samples of the plant effluent were taken just prior to chlorination. Plant effluent flow measurements were made at the Parshall flume located near the chlorination building. Chlorine loadings (lb./day) were read at the chlorinator located in the chlorination building and were recorded.[2]

The chlorine dosage was calculated using the actual chlorine loading and flow data. To determine the effect of chlorine dosage on the kill of total and fecal coliform organisms, the chlorine dosage was varied.

The time of sampling at the outfall was equal to the time of the initial sample (the sample just prior to chlorination) plus the time of flow (contact time) as determined by the dye studies. Bacteriological samples and total chlorine residuals were taken simultaneously at the outfall. Total and fecal coliform concentrations were determined from the bacteriological samples using the membrane filter test. Chlorine residuals were measured with the color comparator.

Periodic bacteriological samples and total chlorine residuals were taken downstream from the outfall. Bacteriological samples were also taken at an upstream station and examined for total and fecal coliform concentration. (See Table A-2 in Appendix A for data.)

[2] The actual amount of chlorine used each day is measured by plant personnel by determining the daily change in weight of the two (2) ton chlorine gas cylinders. The chlorine loading which was read at the chlorinator was compared to the actual amount of chlorine used each day. It was determined that the chlorine loading read at the chlorinator was too high by a factor of 0.878. Therefore, the actual chlorine loading is equal to the chlorine loading read at the chlorinator times 0.878.

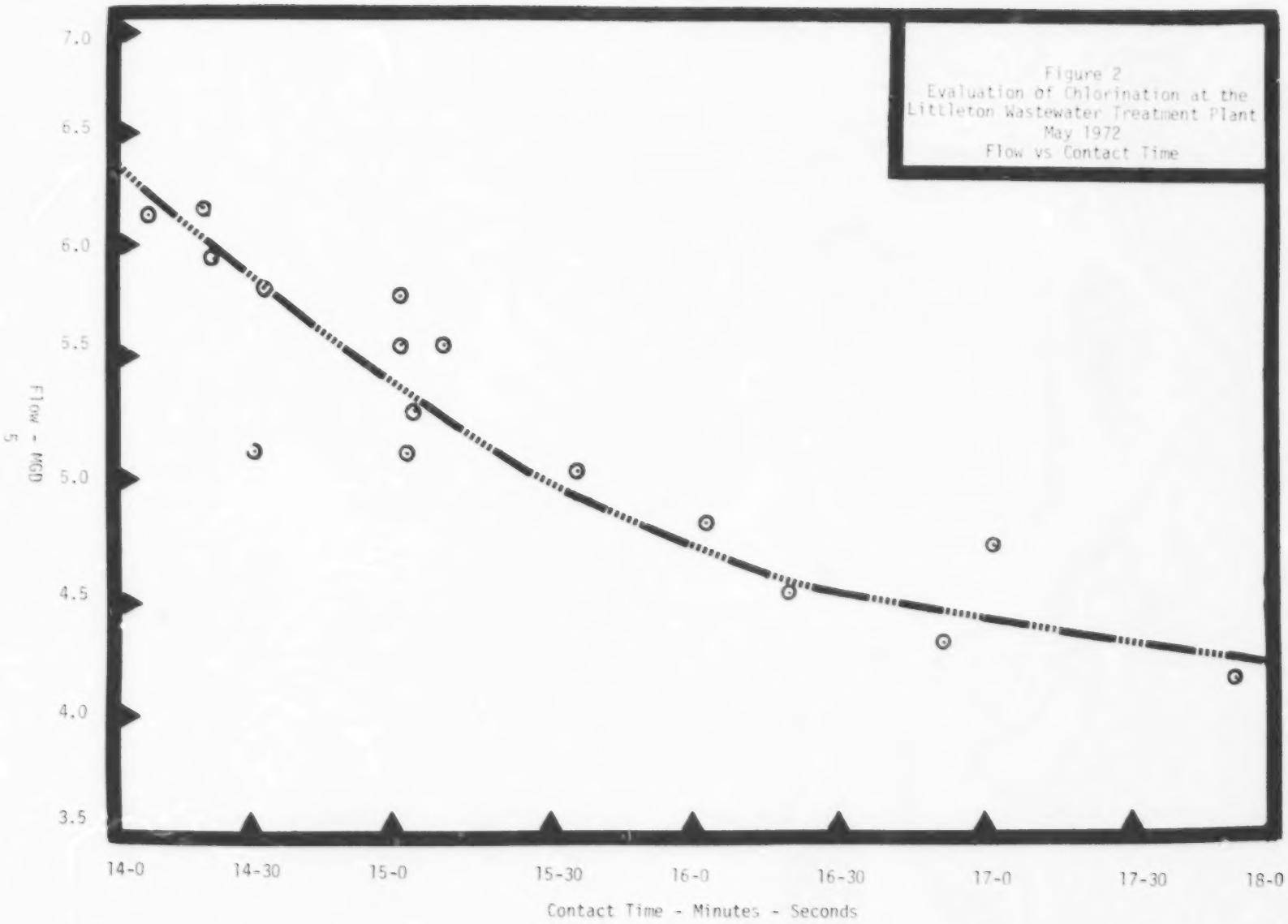
Figure 2
Evaluation of Chlorination at the
Littleton Wastewater Treatment Plant
May 1972
Flow vs Contact Time
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
FLOW - MGD
14-0
14-30
15-0
15-30
16-0
16-30
17-0
17-30
18-0
Contact Time - Minutes - Seconds

V. Analysis of Results

Analysis of the data led to the establishment of various relationships between the measured parameters. These relationships are outlined below.

A. Relationship of Coliforms to Flow

The number of coliform organisms remaining after disinfection is the indicator used to determine the effectiveness of the chlorination system. The primary factors which influence the effectiveness of chlorination are length of chlorine contact time and chlorine dosage.

The concentration of coliform organisms that are to be disinfected would influence the effectiveness of chlorination. Although a specific relationship between total coliform concentration and effluent flow was not determined because of the limited data available, a general trend is indicated by the dotted line in Figure 3. As flow increases, the concentration of total coliforms also increases requiring destruction of more total coliforms at higher flow rates to achieve an equally low coliform concentration after chlorination.

Figure 4 shows that the concentration of fecal coliform organisms neither significantly increases nor decreases with increased flow, although a slight decrease may be interpreted as indicated by the dotted line. Since there is not a significant decrease in the concentration of fecal coliform organisms with increased flow, nearly the same number of fecal coliforms would require destruction for both low and high flows to achieve an equally low coliform concentration after chlorination.

The greatest concentration of total coliforms prior to chlorination exists with higher flow rates. The concentration of fecal coliforms remains nearly the same for both low and high flow rates. It is concluded that the most critical time to achieve effective chlorination occurs at higher flow rates because both high concentrations of coliforms and short chlorine contact times exist.

B. Relationship of Chlorine Residual to Chlorine Dosage

As chlorine is applied to the plant effluent, various reactions take place between the chlorine and bacteria, inorganic and organic compounds (except ammonia and other nitrogenous compounds), and many other substances in the water. These reactions tie up chlorine making it ineffective for further disinfection. The chlorine that is tied up and no longer useful for disinfection purposes is called chlorine demand. When the chlorine demand of the effluent is satisfied, further chlorine dosages remain in the effluent in the form of chlorine residual.

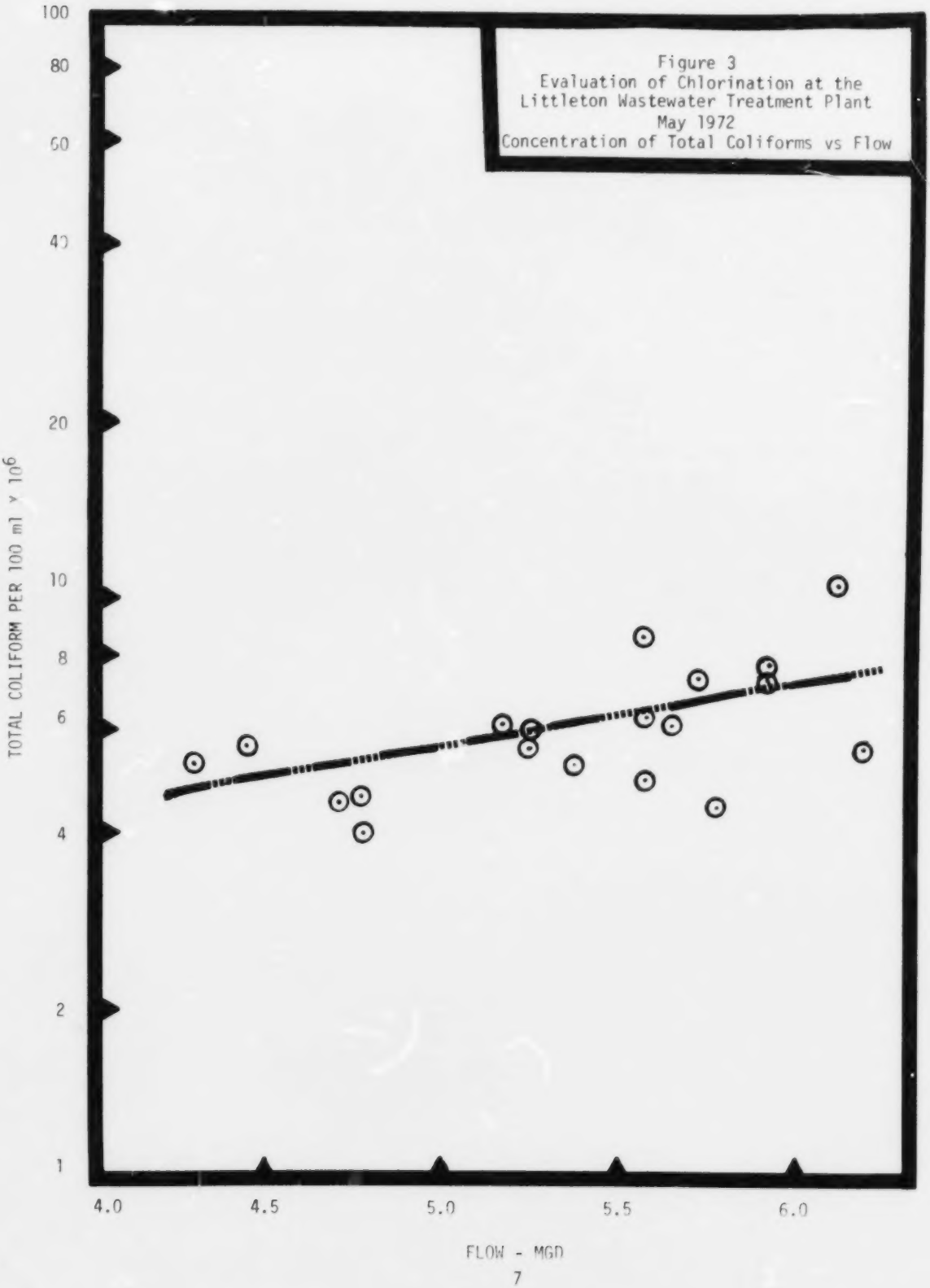
Figure 3
Evaluation of Chlorination at the
Littleton Wastewater Treatment Plant
May 1972
Concentration of Total Coliforms vs Flow
100
80
60
40
20
10
8
6
4
2
1
TOTAL COLIFORM PER 100 ml x 10^6
4.0
4.5
5.0
5.5
6.0
FLOW - MGD

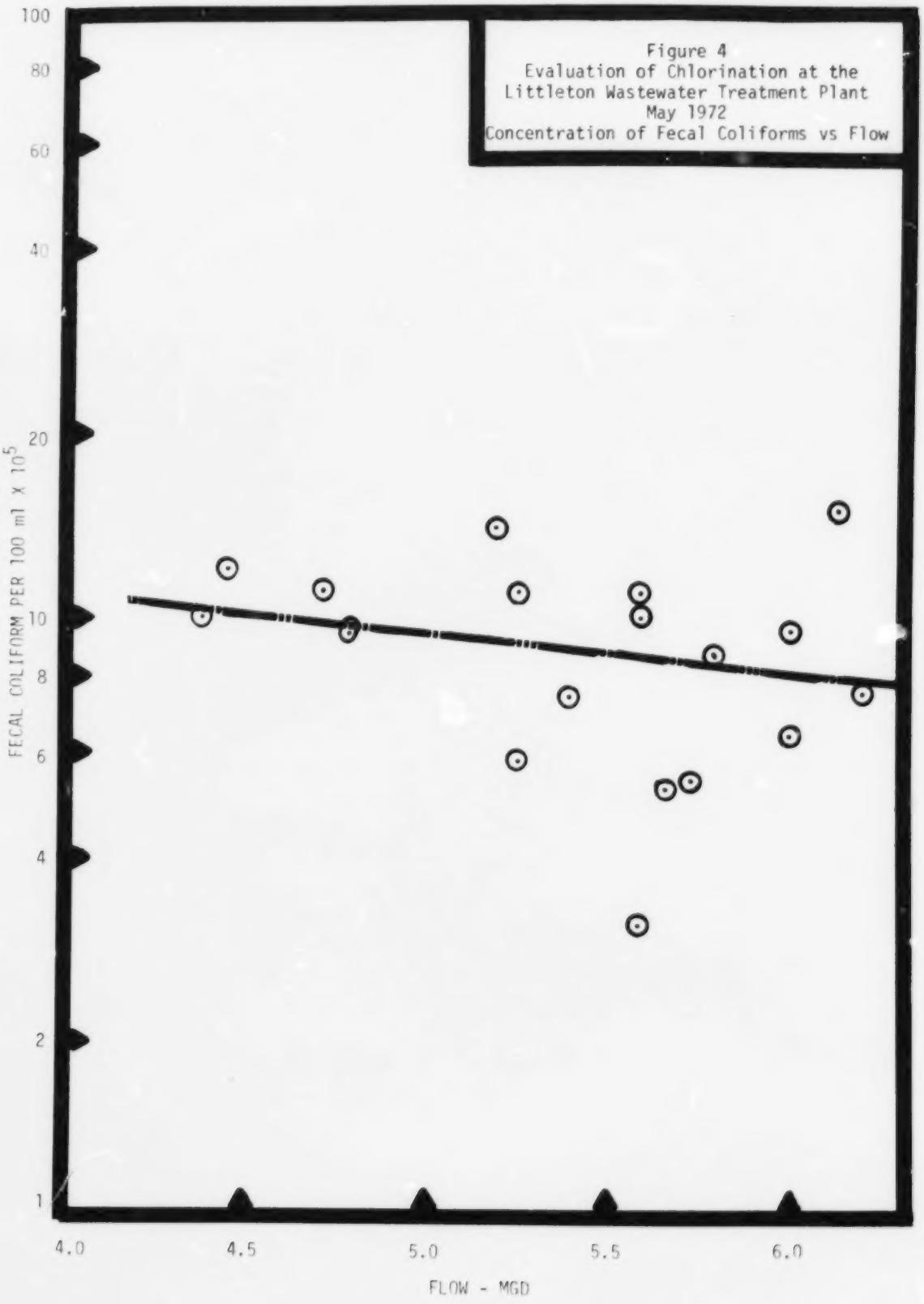
Figure 4
Evaluation of Chlorination at the
Littleton Wastewater Treatment Plant
May 1972
Concentration of Fecal Coliforms vs Flow
100
80
60
40
20
10
8
6
4
2
1
FECAL COLIFORM PER 100 ml X 10^5
4.0
4.5
5.0
5.5
6.0
FLOW - MGD

The chlorine residual exists in various forms depending upon the chlorine dosage applied. At lower chlorine dosages, below what is called breakpoint chlorination, the chlorine dosage reacts with the ammonia and other nitrogenous compounds in the effluent and forms monochlorimines, dichlorimines, and trichlorimines. These chlorimine compounds are disinfectants, with the monochlorimines and dichlorimines having most of the disinfectant power, and are called collectively combined available chlorine. At higher chlorine dosages, above breakpoint chlorination, the chlorine residual exists in the form of hypochlorite ions (OCl^-) or hypochlorous acid (HOCl) and is called free available chlorine.

Figure 5 shows a typical relationship between chlorine dosage and chlorine residual. Initially the chlorine dosage is expended as chlorine demand. After the chlorine demand is satisfied, the chlorine reacts with ammonia and other nitrogenous compounds and forms combined available chlorine. As the chlorine dosage nears the breakpoint, all ammonia is converted to trichlorimines or further oxidized to free nitrogen and other gases and the chlorine residual decreases. Increased chlorine dosages past the breakpoint yields chlorine residuals in the free available form (1).

Figure 6 shows the relationship between the amount of chlorine applied to Littleton's treatment plant effluent (chlorine dosage) and the chlorine residual concentration at the plant outfall. Also, the relationship between the chlorine applied to the plant effluent and the chlorine residual in the South Platte River at a distance of 270 yards downstream from the plant outfall is shown. The chlorine residual data shown in Figure 6 was grouped according to the chlorine dosage applied. Increments of 0.5 mg/l of chlorine dosage was chosen. The arithmetic average chlorine residual within each 0.5 mg/l increment of chlorine dosage was plotted.

Figure 6 shows that as the chlorine dosage increased the chlorine residual at the plant outfall also increased except at chlorine dosages of between 4.75 and 5.25 mg/l (average chlorine dosage of 5.0 mg/l). At this average chlorine dosage of 5.0 mg/l, the chlorine residual decreased as in the typical breakpoint chlorination curve.

Figure 6 also shows that as the chlorine residual in the plant outfall increased or decreased, the chlorine residual in the river also increased or decreased, except at the 7.5 mg/l dosage. The lower chlorine residual for this dosage

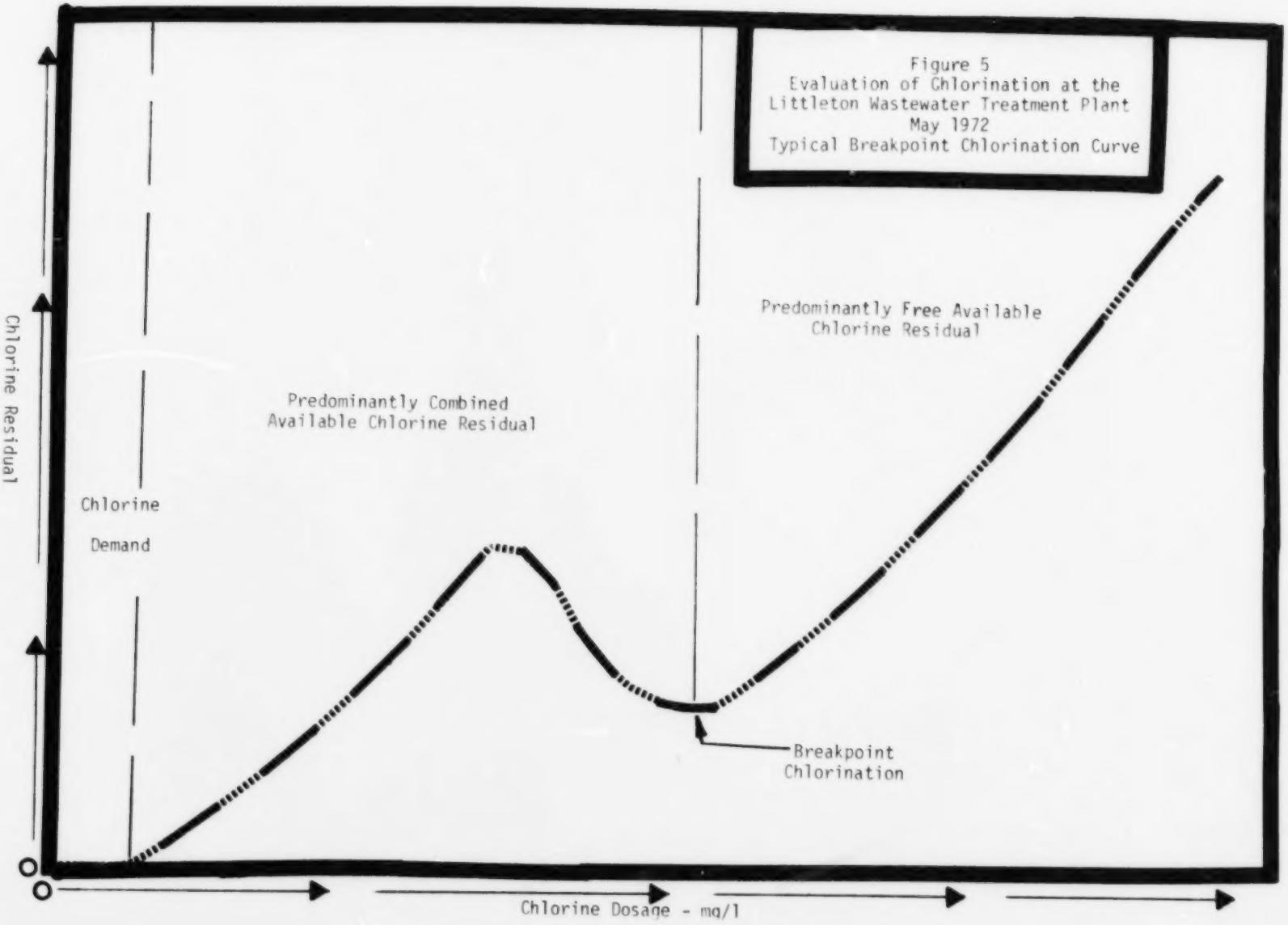
Figure 5
Evaluation of Chlorination at the
Littleton Wastewater Treatment Plant
May 1972
Typical Breakpoint Chlorination Curve
Chlorine Residual
Predominantly Free Available
Chlorine Residual
Predominantly Combined
Available Chlorine Residual
Chlorine
Demand
Breakpoint
Chlorination
Chlorine Dosage - mg/l

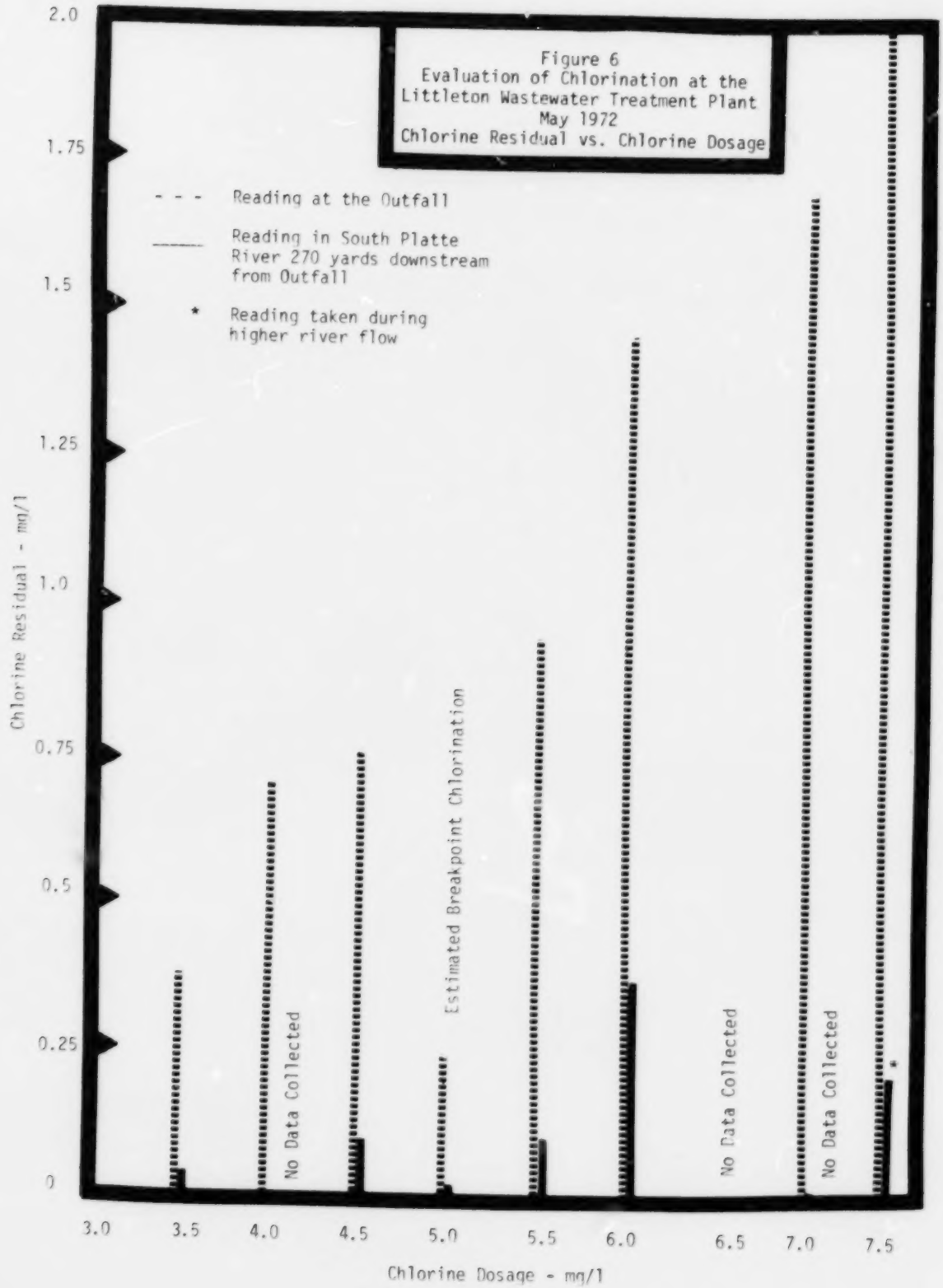
Figure 6
Evaluation of Chlorination at the
Littleton Wastewater Treatment Plant
May 1972
Chlorine Residual vs. Chlorine Dosage
- - - Reading at the Outfall
——— Reading in South Platte River 270 yards downstream from Outfall
* Reading taken during higher river flow
Chlorine Residual - mg/l
2.0
1.75
1.5
1.25
1.0
0.75
0.5
0.25
0
No Data Collected
Estimated Breakpoint Chlorination
No Data Collected
No Data Collected
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
Chlorine Dosage - mg/l

is due to the fact that the river flow was higher during the time that this reading was taken due to heavy rains; therefore, the residual concentration was affected by dilution. At a chlorine dosage of 7.54 mg/l there was a trace chlorine residual a distance of one mile downstream from the Littleton outfall.

Using chlorine to disinfect treated wastewater effluents necessitates the existence of a chlorine residual at the outfall, unless the chlorine is purposely removed by special treatment. This chlorine residual at the outfall causes a chlorine residual in the river which may be deleterious to fish life under conditions of high effluent flow and corresponding low river flow.

Studies indicate that the lethal concentration of chlorine varies with different species of fish. Free available chlorine concentrations of 0.03 mg/l have been reported to have killed rainbow trout, whereas concentrations of 0.1 mg/l have been reported to have not harmed trout. Concentrations of 0.15 to 0.2 mg/l have killed the more tolerant fish species, carp, whereas, concentrations of 1.0 mg/l have been reported to have not harmed carp. The wide discrepancy in the above examples for each species of fish can be attributed to other factors such as pH, temperature, dissolved oxygen, and the synergism and antagism of other pollutants markedly affecting the toxicity of chlorine toward fish. The examples do show that the less tolerant species of fish are affected by lower concentrations of chlorine residual. Studies also indicate that in some instances combined available chlorine is more toxic toward fish than free available chlorine and other studies show the opposite is true (2). In any event, it may be said that relatively small concentrations of chlorine can be detrimental to fish life; hence, every effort should be made to maintain as low a chlorine residual as possible in the outfall and still maintain the bacteriological water quality standards.

Operating personnel at Littleton adjust the chlorine dosage to obtain a chlorine residual of about 0.2 mg/l at the outfall. This 0.2 mg/l residual produces a residual in the river a distance of 270 yards downstream, of about 0.05 mg/l. It should be noted that these samples were taken during relatively high river flow which was due to heavy rains. The exact quantity of river flow was not measured, but was approximately one (1) inch over the top of the face of the Englewood Water Supply Dam at Union Avenue. It would be

expected that the chlorine residual in the river would be higher if the river flow was lower and would consequently increase the chances of having conditions (higher chlorine residual) deleterious to fish, especially the less tolerant species.

C. Relationship of Coliform Concentration to Chlorine Dosage

Disinfection with chlorine is used by Littleton to meet the bacteriological requirement established by the Colorado Water Quality Standards. Figure 7 shows the relationship between chlorine dosage and the concentration of total and fecal coliform organisms. For Figure 7 the coliform data was grouped according to the chlorine dosage. Increments of 0.5 mg/l of chlorine dosage increment was grouped and the logarithmic average coliform concentration was determined. Colorado state standards for coliform concentrations are based upon logarithmic averages.

Figures 6 and 7 show that the concentration of coliform organisms corresponds inversely with the chlorine residual. For example, Figure 6 showed that at breakpoint chlorination there was a decrease in the chlorine residual. Correspondingly, Figure 7 shows that the concentration of coliform organisms increased at breakpoint (i.e., 5 mg/l chlorine dosage), as well as at other points of lower chlorine residual (i.e., 3.5 mg/l chlorine dosage).

Figure 7 also shows that at a chlorine dosage of about 3.5 mg/l, the log average fecal coliform concentration is 300 per 100 ml. (NOTE: 3.5 mg/l is the approximate normal chlorine dosage provided at Littleton.) This concentration of 300 fecal coliforms per 100 ml at the outfall decreased to 52 fecal coliform per 100 ml in the stream at the sampling station 270 yards downstream, meeting the state's bacteriological stream standards. If the stream standards are changed to effluent standards and the limit set at 100 fecal coliforms per 100 ml, additional disinfection will be required. The amount of additional disinfection required is discussed in the following section (Section D).

D. Relationship of Coliform Concentration to Chlorine Dosage Times Contact Time

Both chlorine contact time and chlorine dosage are very important in disinfection. Where other factors are constant, the disinfecting action or the kill of harmful organisms and coliform organisms is directly proportional to the chlorine dosage times the chlorine contact time.

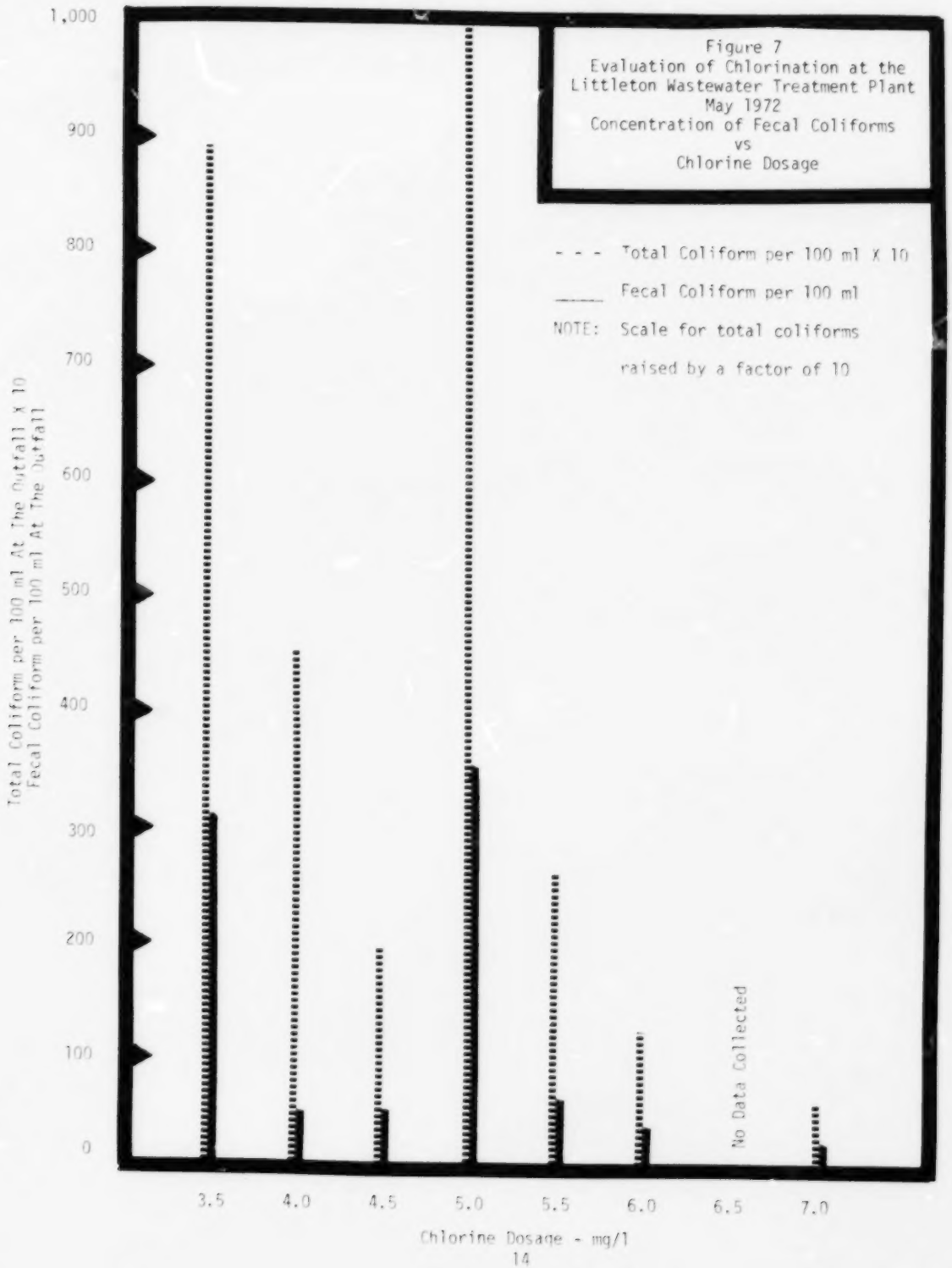
Figure 7
Evaluation of Chlorination at the
Littleton Wastewater Treatment Plant
May 1972
Concentration of Fecal Coliforms
vs
Chlorine Dosage
- - - Total Coliform per 100 ml X 10
_____ Fecal Coliform per 100 ml
NOTE: Scale for total coliforms
raised by a factor of 10
Total Coliform per 100 ml At The Outfall X 10
Fecal Coliform per 100 ml At The Outfall
1,000
900
800
700
600
500
400
300
200
100
0
No Data Collected
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
Chlorine Dosage - mg/l

Figure 8 shows the relationship between the product of chlorine dosage times contact time and total and fecal coliform concentrations at the Littleton outfall. Data was grouped in increments of 10 according to the product of chlorine dosage times contact time. Coliform data within each increment of 10 was grouped and the logarithmic average coliform concentration was determined. Figure 8 shows that more coliforms are killed (i.e., fewer coliforms are present at the outfall) as the product of chlorine dosage times contact time is increased until the breakpoint is achieved.

Using Figure 8, various combinations of chlorine dosages and contact times can theoretically be determined to obtain a given coliform count at the outfall. For economic reasons the lowest possible factor to obtain the desired or required coliform count should be used. The lowest factor would require a minimum amount of chlorine and a minimum contact time resulting in a lower operating cost and a smaller chlorine contact basin.

If the present Colorado Water Quality Standards are modified to effluent standards and are upgraded to require a logarithmic average fecal coliform concentration at the outfall of less than 100 per 100 ml., the product of the chlorine dosage times contact time must be at least 65. However, the following limitations apply: the chlorine dosage must be greater than the chlorine demand and the chlorine dosage must be either above or below that required for breakpoint chlorination.

To obtain the product of 65 under present operating conditions (i.e., with a minimum contact time of 14 minutes) the chlorine dosage would have to be 4.64 mg/l. This high chlorine dosage would raise the chlorine residual at the outfall to about 0.75 mg/l. This residual at the outfall would raise the chlorine residual in the river (270 yards downstream) to about 0.1 mg/l which would be more detrimental to fish life than the present river chlorine residual of 0.05 mg/l.

A better combination of chlorine dosage and contact time to obtain a product of at least 65, and a fecal coliform concentration of less than 100 per 100 ml., would be to use the present chlorine dosage of 3.5 mg/l and increase the chlorine contact time to 19 minutes. This combination would require construction of a chlorine contact basin at Littleton since a 19 minute contact time is not available with present facilities. With even longer contact times, it may be possible to use lower chlorine dosages. Lower

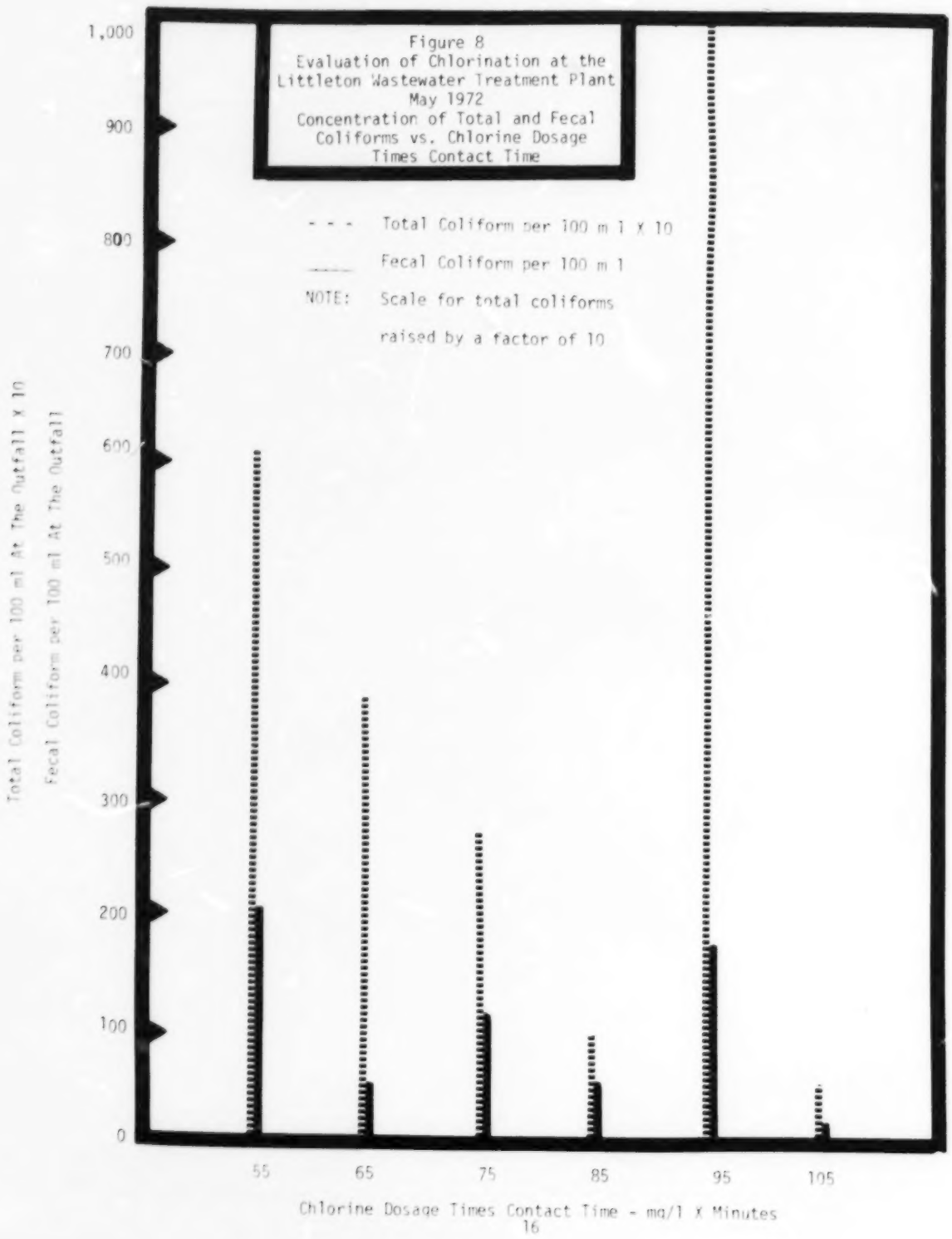
Figure 8
Evaluation of Chlorination at the
Littleton Wastewater Treatment Plant
May 1972
Concentration of Total and Fecal
Coliforms vs. Chlorine Dosage
Times Contact Time
- - - Total Coliform per 100 m l X 10
Fecal Coliform per 100 m l
NOTE: Scale for total coliforms
raised by a factor of 10
Total Coliform per 100 ml At The Outfall X 10
Fecal Coliform per 100 ml At The Outfall
1,000
900
800
700
600
500
400
300
200
100
0
55
65
75
85
95
105
Chlorine Dosage Times Contact Time - mg/l X Minutes

chlorine dosages would reduce the chlorine residual going to the river. In turn the chlorine residual in the river would be reduced to a level that would be less detrimental to fish and other aquatic life. A reduction in the daily cost of chlorination would also occur. The construction of a chlorine contact basin would apparently add much more flexibility to the operation of the disinfection unit at the Littleton treatment plant.

VI. Summary and Conclusions

For the average daily flow of 4.25 MGD at the Littleton wastewater treatment plant, the length of chlorine contact time is about 18 minutes. During the survey, the highest recorded flow during any one day was 6.19 MGD and the resulting contact time was about 14 minutes. Since length of contact time is one of the two most important factors (chlorine dosage is the second factor) in disinfection and since high flows yield shorter contact times, the effectiveness of chlorination at Littleton was studied during periods of high plant effluent flow.

The concentration of total coliform organisms after secondary treatment and prior to chlorination increased as the effluent flow increased. The concentration of fecal coliform organisms did not significantly increase or decrease as the flow increased. The concentration of coliform organisms that are to be disinfected would directly influence the effectiveness of chlorination. The most critical time to achieve effective chlorination occurs at higher flow rates because both high concentrations of coliforms and short chlorine contact times exist.

Presently the operational mode at Littleton, with respect to chlorination, is to adjust the chlorine dosage to obtain a chlorine residual at the outfall of 0.2 mg/l. In most cases a chlorine dosage of about 3.5 mg/l is needed to maintain the desired 0.2 mg/l chlorine residual.

During this survey, the chlorine dosage was adjusted from 3.41 mg/l to 7.54 mg/l to determine the effect of various chlorine dosages on total and fecal coliform concentrations at the plant outfall. The chlorine residuals were monitored at the outfall and in the South Platte River 270 yards downstream from the plant outfall. The chlorine residual at the plant outfall and in the river increased as the chlorine dosage increased except at breakpoint chlorination which occurred at a chlorine dosage of about 5.0 mg/l.

The present operational mode at Littleton with respect to chlorination (a chlorine dosage of about 3.5 mg/l) gives a chlorine residual at the outfall of about 0.2 mg/l and a chlorine residual in the South Platte River 270 yards downstream of about 0.05 mg/l. The chlorine residual in the river increased or decreased inversly as the flow of the river increased or decreased. The 0.05 mg/l chlorine residual occurred when the river flow was relatively high. Literature reveals that a chlorine residual of 0.05 mg/l may have a detrimental effect on fish life, especially the less tolerant species of fish. If the chlorine dosage would be increased, thus increasing the chlorine residual at the outfall, or the river flow would decrease, the chlorine residual in the river would be raised thus increasing the possibility of an even greater detrimental effect on fish life.

To determine the effectiveness of chlorination with varied chlorine dosages, bacteriological samples were taken at the plant outfall and total and fecal coliform tests were run on these samples using the membrane filter test. The total and fecal coliform concentration at the outfall varies inversely with the chlorine residual at the outfall. The present operational mode at Littleton with respect to chlorination gave a logarithmic average of 300 fecal coliforms per 100 ml. This average effluent discharge did not cause a violation of the Colorado Water Quality Bacteriological Standard of 1000 fecal coliform per 100 ml in the South Platte River. For the chlorine dosages that were studied, dosages of about 5.0 mg/l, breakpoint chlorination, yielded the highest total and fecal coliform concentration (10,000 per 100 ml. and 350 per 100 ml. respectively) in the effluent.

With the ever increasing emphasis on upgrading the quality of our rivers and streams, it is possible that the bacteriological water quality standards may be modified to include effluent standards which may require a logarithmetric average of 100 fecal coliforms per 100 ml. At Littleton, additional disinfection would be required to meet this higher standard. Two parameters, chlorine dosage and contact time, may be adjusted to obtain the additional disinfection. With the present design at Littleton (i.e., a minimum chlorine contact time of 14 minutes) the chlorine dosage required to reach the 100 fecal coliform per 100 ml. concentration would be about 4.64 mg/l. This high chlorine dosage would raise the chlorine residual at the outfall to about 0.75 mg/l. The residual of 0.75 mg/l at the outfall would raise the chlorine residual in the river (270 yards downstream from the outfall) to about 0.1 mg/l which would be more detrimental to fish life than the present river chlorine residual of 0.05 mg/l.

A better combination of chlorine dosage and contact time to achieve the additional disinfection and decrease the chlorine residual in the river would be to increase the chlorine contact time and decrease the chlorine dosage. This combination would reduce the chlorine residual at the outfall. In turn, the chlorine residual in the river would be reduced to a level that would be less detrimental to fish and other aquatic life. Additionally, a reduction in the daily cost of chlorination would occur. However, the longer contact time necessitates the construction of a chlorine contact basin.

VII. Recommendations

The following recommendations are made:

1. If the present Colorado Water Quality Standards are modified to include effluent standards which require 100 fecal coliforms per 100 ml. in the plant effluent, a chlorine contact basin would be necessary to provide the most satisfactory disinfection at the Littleton plant.

2. Although higher chlorine dosages (up to breakpoint chlorination and after breakpoint chlorination) would achieve better disinfection, present objectives, to include meeting present Colorado Water Quality Standards and maintaining a low chlorine residual in the river, will be best achieved by maintaining a chlorine dosage of 3.5 mg/l. Therefore, a dosage of about 3.5 mg/l should be continued at the Littleton treatment plant.

   To obtain a chlorine dosage of 3.5 mg/l the following chlorine loadings (lb./day) at various flow rates should be followed: See Table I.

3. The scale for measuring chlorine load released by the chlorinator at Littleton gives a reading which is 0.878 times larger than the actual chlorine load. The chlorine load scale should be corrected to show the actual chlorine loading.

4. At Littleton a chlorine dosage between 4.75 and 5.25 mg/l is not as effective for disinfection purposes as the lower chlorine dosage of 3.5 mg/l. A chlorine dosage between 4.75 and 5.25 mg/l is in the breakpoint chlorination range. For more effective disinfection the chlorine dosage should not be set between 4.75 and 5.25 mg/l.

TABLE I

Evaluation of Chlorination at the Littleton
Wastewater Treatment Plant

May 1972

Recommended Chlorine Loadings for Various
Flows with Present Treatment Plant Design

Chlorine Dosage (mg/l)	Flow (MGD)	Recommended Chlorine Loading (lb./day)	*Required Setting On Chlorinator at Littleton (lb./day)
3.5	3.5	102	116
3.5	4.0	117	133
3.5	4.5	131	150
3.5	5.0	146	166
3.5	5.5	160	183
3.5	6.0	175	200

* The chlorine load setting on the chlorinator at Littleton must be greater than the recommended chlorine loading by a factor of 0.878.

APPENDIX A

Survey Data

TABLE A-1

Evaluation of Chlorination at the
Littleton Wastewater Treatment Plant

May 1972

Raw Data for Contact Time Measurement

Date	Time	Parshall Flume Head	Parshall Flume Width	Flow	Contact Time	
		(Ft.)	(In.)	(MGD)	(Min.)	(Sec.)
May 16	1040	1.27	18	5.60	15	9
May 16	1160	1.27	18	5.60	15	9
May 16	1355	1.19	18	5.07	15	36
May 16	1510	1.14	18	4.74	17	1
May 17	0800	1.05	18	4.18	17	45
May 17	1100	1.30	18	5.81	15	0
May 17	1411	1.11	18	4.55	16	20
May 18	1007	1.33	18	5.97	14	18
May 18	1100	1.27	18	5.60	15	0
May 22	1026	1.35	18	6.12	14	7
May 22	1320	1.20	18	5.13	15	1
May 23	0922	1.39	18	6.19	14	19
May 23	1044	1.24	18	5.38	14	55
May 23	1411	1.09	18	4.44	16	45
May 24	0945	1.20	18	5.13	14	30
May 24	1015	1.31	18	5.85	14	33
May 24	1110	1.23	18	5.32	15	4
May 24	1306	1.16	18	4.85	16	4

TABLE A-2
EVALUATION OF CHLORINATION FOR THE
LITTLETON WASTEWATER TREATMENT PLANT
MAY 1972

Tabulation of Chlorination and Bacteriological Data

Station	Date	Time	Flow (MGD)	Chlorine Dosage (MG/L)	Chlorine Residual (MG/L)	Contact Time (Min)	Contact Time (Sec)	Total Coliform Col/100 ml	Fecal Coliform Col/100 ml	Remarks
I	5/16	1025	5.58	3.78	-		-	8,600,000	1,100,000	
II	"	1039	5.58	-	1.2	14	50	1,500	50	
I	"	1145	5.58	4.15	-		-	4,900,000	310,000	
II	"	1200	5.58	-	0.5	14	50	1,200	57	
I	"	1455	4.78	4.41	-		-	4,600,000	940,000	
II	"	1515	4.78	-	0.8	15	50	4,200	40	
III	"	1520	-	-	0.1		-	970	15	
I	5/17	0955	5.65	4.48	-		-	6,100,000	520,000	
II	"	1010	5.65	-	0.9	14	44	1,300	100	
I	"	1100	5.78	4.73	-		-	4,400,000	870,000	
II	"	1115	5.78	-	0.5	14	36	3,000	40	
I	"	1145	5.25	5.02	-		-	5,600,000	1,200,000	

TABLE A-2 (Cont.)

Station	Date	Time	Flow (MGD)	Chlorine Dosage (MG/l)	Chlorine Residual (MG/L)	Contact Time (Min)	Contact Time (Sec)	Total Coliform Col/100 ml	Fecal Coliform Col/100 ml	Remarks
II	5/17	1200	5.25	-	0.25	15	12	10,000	350	
I	"	1345	4.71	5.14	-		-	4,500,000	1,200,000	
II	"	1400	4.71	-	TR	16	4	300	30	Questionable Bacteriological Data
I	5/17	1555	4.38	5.53	-		-	5,300,000	1,000,000	
II	5/17	1615	4.38	-	0.4	17	30	10,000	180	
III	5/17	1620	-	-	0.1		-	-	-	
I	"	2047	5.18	5.48	-		-	6,100,000	1,400,000	
II	"	2105	5.18	-	1.5	15	17	660	20	
I	"	2130	5.25	5.82	-		-	6,000,000	580,000	
II	"	2150	5.25	-	1.4	15	11	760	20	
III	"	2155	-	-	0.5		-	-	-	
I	5/18	0910	5.72	6.08	-		-	7,300,000	540,000	

TABLE A-2 (Cont.)

Station	Date	Time	Flow (MGD)	Chlorine Dosage (MG/L)	Chlorine Residual (MG/L)	Contact Time (Min)	Contact Time (Sec)	Total Coliform Col/100 ml	Fecal Coliform Col/100 ml	Remarks
II	5/18	0930	5.72	-	1.5	14	41	2,000	60	
III	"	0935	-	-	0.25		-	-	-	Stream Flow Higher Than Previous Days
I	"	1007	5.92	7.11	-		-	7,700,000	640,000	
II	"	1023	5.92	-	1.7	14	27	570	20	
I	5/18	1100	5.58	7.54	-		-	6,300,000	1,000,000	
II	5/18	1120	5.58	-	2.0	14	48	640	100	Questionable Bacteriological Data
III	"	1200	-	-	0.2		-	-	-	
IV	"	1215	-	-	TR		-	-	-	
I	5/22	0927	5.92	3.46	-		-	7,200,000	950,000	Stream Flow Higher Than May 18
II	5/22	0942	5.92	-	0.6	14	28	5,200	270	
V	"	0950	-	-	-		-	200	170	
III	"	1000	-	-	TR		-	830	160	
I	"	1041	6.12	3.45	-		-	11,000,000	1,500,000	
II	"	1055	6.12	-	0.3	14	16	44,000	890	

TABLE A-2 (Cont.)

Station	Date	Time	Flow (MGD)	Chlorine Dosage (MG/L)	Chlorine Residual (MG/L)	Contact Time (Min)	Contact Time (Sec)	Total Coliform Col/100 ml	Fecal Coliform Col/100 ml	Remarks
I	5/22	1405	4.78	3.86	-		-	4,000,000	950,000	
II	"	1421	4.78	-	0.4	15	55	52,000	50	
I	5/23	0920	6.19	3.41	-		-	5,500,000	750,000	Stream Flow Same As May 22
II	"	0935	6.19	-	0.3	14	12	15,000	470	
III	"	0955	-	-	0.1		-	860	30	
I	"	1131	5.38	3.52	-		-	5,200,000	740,000	
II	"	1145	5.38	-	0.3	15	3	1,800	80	
V	"	1152	-	-	-		-	170	40	
IV	"	1211	_	-	TR		-	770	100	
I	"	1411	4.45	4.26	-		-	5,600,000	1,200,000	
II	"	1424	4.45	-	0.8	17	0	760	40	

Station I - Sewage Treatment Plant Effluent - Prior to Chlorination
Station II - Sewage Treatment Plant Effluent - At the Outfall
Station III - South Platte River - 270 Yards Downstream from Littleton Outfall
Station IV - South Platte River at Oxford Street Bridge (1 Mile Downstream from Littleton Outfall)
Station V - South Platte River - Upstream from Littleton Outfall

APPENDIX B

References

1. Sawyer, Clair N., Chemistry for Sanitary Engineers, McGraw Hill Book Company, Inc., New York, New York, (1960) pp. 246-256.

2. McKee, Jack E. and Wolf, Harold W., Water Quality Criteria, California State Water Resources Control Board, Sacramento, California.